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Appraisal of open software for finite element simulation of 2D metal sheet laser cut

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Abstract

FEA simulation of thermal metal cutting is central to interactive design and manufacturing. It is therefore relevant to assess the applicability of FEA open software to simulate 2D heat transfer in metal sheet laser cuts. Application of open source code (e.g. FreeFem++, FEniCS, MOOSE) makes possible additional scenarios (e.g. parallel, CUDA, etc.), with lower costs. However, a precise assessment is required on the scenarios in which open software can be a sound alternative to a commercial one. This article contributes in this regard, by presenting a comparison of the aforementioned freeware FEM software for the simulation of heat transfer in thin (i.e. 2D) sheets, subject to a gliding laser point source. We use the commercial ABAQUS software as the reference to compare such open software. A convective linear thin sheet heat transfer model, with and without material removal is used. This article does not intend a full design of computer experiments. Our partial assessment shows that the thin sheet approximation
Loading [MathJax]/jax/output/HTML-CSS/jax.js ror for linear alumina sheets. Under mesh resolutions better than 10 m , the open and reference software temperature

differ in at most 1 % of the temperature prediction. Ongoing work includes adaptive re-meshing, nonlinearities, sheet stress analysis and Mach (also called ‘relativistic’) effects.

Keywords

Laser machining Sheet cutting Heat transfer Finite element analysis

Abbreviations

FEM/FEA
Finite element method/finite element analysis

$\mathbf{x}, t$
Coordinates describing the spatial $[x, y]$ and temporal $t \geq 0$ domain of the simulation ($[m, m]$, s)

$u = u(\mathbf{x}, t)$
Temperature distribution along the sheet at a given time (K)

ρ

Sheet metal density $\left(\frac{}{\mathrm{m}^3}\right)$

c_p

Sheet specific heat capacity $\left(\frac{}{\mathrm{kg\,K}}\right)$

k

Sheet thermal conductivity $\left(\frac{}{\mathrm{m\,K}}\right)$

R
Sheet reflectivity i.e., portion of the laser energy that is not absorbed by the sheet ($0 \leq R \leq 1$)

Δz
Sheet thickness (m)

$q = q(u)$

Heat loss due to convection at the sheet surface $\left(\frac{}{\mathrm{m}^2}\right)$

h

Natural convection coefficient of the sheet surrounding medium $\left(\frac{}{\mathrm{m}^2\,\mathrm{K}}\right)$

u_∞
Temperature of the sheet surrounding medium (K)

$S = S(\mathbf{x}, t)$

Laser power density distribution along the sheet at a given time $\left(\frac{}{\mathrm{m}^3}\right)$

P
Laser power (W)

σ
Gaussian laser model's parameter (m)

$\mathbf{x_0 = x_0}(t)$
Laser spot 2D coordinates $[x_0(t), y_0(t)]$ at a given time $([m, m])$

v
Laser scanning speed $\left(\frac{}{\mathrm{s}}\right)$

ε
Kerf width of the laser (m)

$u_{ref} = u_{ref}(\mathbf{x}, t)$
Reference temperature used to measure the relative error of a given solution (K). This article considers the temperature distribution obtained by the ABAQUS software as reference

$E = E(\mathbf{x}, t)$
Relative error distribution of a software approximation w.r.t. u_{ref} along the sheet at a given time

$ME = ME(t)$
Maximum relative error of a software temperature approximation w.r.t. u_{ref} at a given time

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